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# IMAGE

## MIDEX Mission

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### Project Data Management Plan

Draft

National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Md 20771

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National Aeronautics and Space Administration  
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Project Data Management Plan for the IMAGE Mission

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# 1.0 - Introduction

This document describes the Project Data Management Plan (PDMP) for the Imager for Magnetopause-to-Aurora (IMAGE) mission. IMAGE is NASA's first medium-sized Explorer mission (or MIDEX) whose development cost cap for payload and spacecraft is approximately \$68 million dollars (FY94). IMAGE also has a mission operations and data analysis cost cap of \$15 million dollars (FY94). The IMAGE PDMP is designed to be consistent with the IMAGE Level-1 Requirements Definition document.

## 1.1 - Purpose and Scope

This data management plan describes the generation and delivery of IMAGE science data products, institutional responsibilities for data analysis, and the transfer of archival data products to the National Space Science Data Center (NSSDC). Covered in this plan are:

1. Brief description of the instruments
2. Description of the data flow
3. Description of the science data products
4. Processing requirements and facilities
5. Policies for access and use of IMAGE data
6. Data product documentation

It is important to note that the IMAGE mission support two data telemetry streams; a science data stream (full resolution data stored and forwarded on command) and a continuous low bit rate (~500 b/s) real-time data link. The real-time data link will be used by NOAA in their Space Environment Center (SEC) for space weather analysis and alerts. The management of the data from the IMAGE real-time data link will not be covered in this plan. At this time most of the details of that link have not been defined and are the responsibility of NOAA.

## 1.2 - PDMP Development, Maintenance, and Management Responsibility

The IMAGE Project Office at Goddard Space Flight Center (GSFC), Code 410, is responsible for the development, maintenance, and management of the PDMP until IMAGE has transitioned to an operational mission after launch. Responsibility for the plan remains with the IMAGE Mission Manager, Mr. Frank Volpe until 30 days after launch. After signature release and until transition to an operational mission, the IMAGE PDMP will be modified and updated as required in accordance with the Configuration Management Plan for Midex Missions.

After launch and instrument check the responsibility for the IMAGE mission will be transitioned to the Orbiting Satellites Project (OSP, Code 630.1) within the Space Sciences Directorate. The responsibility for the IMAGE PDMP will also transition to OSP.

# 2.0 - Project Overview

The IMAGE mission was selected as a result of AO-95-OSS-02 for MIDEX missions. The Phase B study began on May 10, 1996, and the Mission Confirmation Review was held on February 25-27, 1997. Mission Confirmation was granted on March 31, 1997. The IMAGE mission is scheduled to be launched in January 2000.

## 2.1 - Science Objectives

The overall science objective of IMAGE is to determine the global response of the magnetosphere to changing conditions in the solar wind. Three fundamental questions which must be addressed by IMAGE to accomplish its primary objective are:

- What is the mechanism for injecting plasma into the magnetosphere on substorm and magnetic storm time scales?
- What is the directly driven response of the magnetosphere to solar wind changes?
- How and where are magnetospheric plasmas energized, transported, and subsequently lost during storms and substorms?

IMAGE will address these objectives in unique ways using neutral atom imaging (NAI) over an energy range from 10 eV to 200 keV, far ultraviolet imaging (FUV) from 121 to 190 nm, extreme ultraviolet imaging (EUV) at 30.4 nm, and radio plasma imaging (RPI) over the density range from 0.1 to 10<sup>5</sup> cm<sup>-3</sup> throughout the magnetosphere.

## 2.2 - Data Acquisition and Access Overview

The IMAGE mission will operate with a near 100% duty cycle with all instruments in their baseline operational modes. The IMAGE Level-0 data will be processed into Level-1 data (Browse Products) within 24 hours after their receipt in the Science and Mission Operations Control Center (SMOC) at GSFC. These data products will be transferred to the NSSDC and posted immediately on the world wide web for use by the international community of scientists and the public. Level-2 data products will be posted on the web and at NSSDC as they are generated.

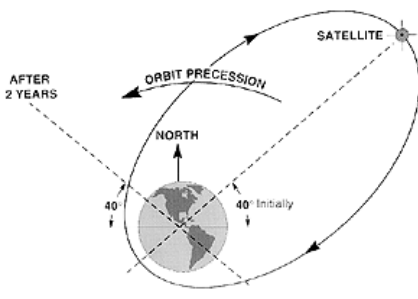
<b>Orbit Description</b>	inclination: 90° apogee: 44,590 km perigee: 1000 km period: 13.5 hr.
<b>Launch Date</b>	1 January 2000
<b>Launch Vehicle</b>	Delta 7326-9.5
<b>Nominal Mission Duration</b>	2 years
<b>Potential Mission Life</b>	5 years
<b>Spacecraft Mass</b>	~500 kg
<b>Spin Rate</b>	0.5 rpm
<b>Attitude Control Accuracy</b>	spin axis: 0.1° spin phase: 0.1°
<b>On-Board Data Storage Capacity</b>	2 GB
<b>Continuous Data Acquisition Rate</b>	2.5 Mbits/sec

**Table 2.1** IMAGE Mission Summary

### 2.3 - Summary of Mission Operations

The IMAGE mission summary is shown in Table 2.1. After launch and initial activation of the IMAGE spacecraft systems, the attitude determination and control system (ADAC) will orient the spacecraft spin axis perpendicular to the orbit plane to within 1°. The ADAC will maintain a spin rate of at least 0.5 rpm while deploying the four RPI radial wire antennas (x and y axis). After full extension of the x and y axis antennas, the spacecraft will deploy the two axial (z axis) antennas. The full deployment for all of the RPI antennas should take approximately 30 days. After completion of the antenna deployment the IMAGE spacecraft will be spin stabilized (~0.5 rpm) in an 90° inclination orbit of approximately 1000 km perigee by 7 Earth radii ( $R_E$ ) apogee.

The orbital evolution over the two-year mission life is illustrated in Fig. 2.1. The spacecraft will operate in a store-and-forward mode with data downlinks of 30 minutes once per orbit to the Deep Space Network (DSN). Command uplinks are planned for once per week.



**Fig. 2.1** IMAGE orbital evolution

### 3.0 - Science Instrumentation

The science payload for IMAGE consists of instrumentation for obtaining images of plasma regions in the Earth's magnetosphere. The four types of imaging techniques used by IMAGE are: neutral atom imaging (NAI), far ultraviolet imaging (FUV), extreme ultraviolet imaging (EUV), and radio plasma imaging (RPI). There are 3 instruments used in making NAI measurements. These instruments are: the Low Energy Neutral Atom (LENA) imager, the Medium Neutral Atom (MENA), and the High Energy Neutral Atom (HENA) imager. Each of these instruments cover specific energy ranges and utilize a variety of different instrument technologies. There are 3 instruments utilizing photons for imaging. These instruments are: the Extreme Ultraviolet (EUV), three instruments in the Far Ultraviolet (FUV) frequency range (the Spectrographic Imager (SI), Wideband Imaging Camera (WIC), the Geocoronal (GEO) imager). Finally, very long wavelength remote sounding will be accomplished with the Radio Plasma Imager (RPI). As proposed, the performance requirements for these IMAGE instruments are listed in Table 3.1 below. It is important to note that nearly all the IMAGE instruments will exceed these requirements.

The minimum time resolution for images from all instruments, except the RPI, is the spacecraft spin period of two minutes. The RPI will have modes which will allow density profile determination on a time scale as short as 1 minute and radio "skymaps" or images at specific frequencies in seconds. For the other instruments, images can be constructed from data taken over multiple spin periods. The IMAGE Science Team will have the responsibility to generate and validate the data products but claim no proprietary data rights to any of the data.

Image	Measurements	Critical Measurement Requirements
NAI	Neutral atom composition and energy-resolved images over three energy ranges: 10-300 eV (LENA) 1-30 keV (MENA) 10-200 keV (HENA)	FOV: 90° (image ring current at apogee). Angular Resolution: 8° x 8° Energy Resolution ( $\Delta E/E$ ): 0.8 Composition: distinguish H and O in magnetospheric and ionospheric sources, interstellar neutrals and solar wind.

		<i>Image Time:</i> 4 minutes (resolve substorm development). <i>Sensitivity:</i> effective area 1 cm <sup>2</sup> for each sensor.
<b>EUV</b>	30.4 nm imaging of plasmasphere He <sup>+</sup> column densities.	<i>FOV:</i> 90° (image plasmasphere from apogee). <i>Spatial Resolution:</i> 0.1 Earth radius from apogee. <i>Image Time:</i> several minutes to hours (resolve plasmaspheric processes).
<b>FUV</b>	Far ultraviolet imaging of the geocorona at 121.6 nm (GEO) and the aurora at 140-190 nm (WIC) and 121.6 and 135.6 nm (SI)	<i>Spatial Resolution:</i> 70 km (WIC), 90 km (SI) <i>Spectral Resolution:</i> separate cold geocorona H from hot proton precipitation (1~0.2 nm near 121.6 nm); reject 130.4 nm and select 135.6 nm electron aurora emissions. <i>Image Time:</i> 2 minutes (resolve auroral activity).
<b>RPI</b>	Remote sensing of electron densities and magnetospheric boundary locations using radio sounding.	<i>Density range:</i> 0.1-10 <sup>5</sup> cm <sup>-3</sup> (determine electron density from inner plasmasphere to magnetopause). <i>Spatial resolution:</i> 500 km (resolve density structures at the magnetopause and plasmopause). <i>Image Time:</i> 1 minute (resolve changes in boundary locations).

**Table 3.1** Instrumentation Required to Meet Science Objectives

### 3.1 - Neutral Atom Imaging (NAI) Instrument Performance Requirements

The science requirements driving the NAI instrumentation for IMAGE are (1) to image the inner magnetosphere including the ring current on a time scale of 300 seconds and (2) to resolve the major species contributing to neutral atom fluxes. To meet these requirements a suite of three NAI instruments will provide angle, energy, and composition-resolved images at energies from 10 eV to 500 keV.

IMAGE will carry three NAI instruments because of the different techniques that apply to low (0.01 to 0.5 keV), medium (1 to 30 keV), and high (10 to 500 keV) neutral atoms. The detailed instrument performance requirements for the NAI instruments are shown in Table 3.2.

Angular information is obtained over 90° fans with angular resolution between 4° x 4° and 8° x 8° depending on species and energy. Spacecraft spin is used to obtain angular information in the orthogonal (azimuthal) direction. All three instruments have collimators that consist of serrated, blackened surfaces to reduce internal scattering. The collimators contain deflection potentials of 10 kV that deflect and absorb charged particles below 100 keV/e. Small broom magnets remove electrons with energies <200 keV.

	<b>LENA</b>	<b>MENA</b>	<b>HENA</b>
<b>Energy range [keV]</b>	0.01 - 0.3	1-30	10-500
<b>Energy resolution [<math>\Delta E/E</math>]</b>	0.8	0.8	3 keV
<b>Instantaneous FOV [deg]</b>	8 x 90	4 x 107	90 x 120
<b>Total FOV [deg]</b>	90 x 360	107 x 360	120 x 360
<b>Pixel resolution [deg]</b>	8 x 8	4 x 8	4 x 4
<b>Geometric factor [cm<sup>2</sup>sr]</b>	0.2	0.07	1.6
<b>Pixel sensitivity [cts/atom cm<sup>2</sup>sr eV/eV]</b>	7x10 <sup>-4</sup>	4x10 <sup>-3</sup>	4.5x10 <sup>-3</sup>
<b>Image time [s]</b>	120	120	120
<b>Pixel array dimensions M=masses, E=Energies, A=Angles</b>	2M4E11A	2M16E32A	4M16E32A
<b>UV rejection</b>	10 <sup>-7</sup>	10 <sup>-7</sup>	10 <sup>-9</sup>
<b>Electron rejection</b>	10 <sup>-10</sup>	10 <sup>-5</sup>	10 <sup>-5</sup>
<b>Ion rejection</b>	10 <sup>-8</sup>	10 <sup>-5</sup>	10 <sup>-5</sup>

**Table 3.2** NAI Instrument Performance Parameters

#### 3.1.1 - Low Energy Neutral Atom [LENA] Imager

LENA [Ghielmetti et al., 1994] combines standard plasma analyzer techniques with cesiated neutral-to-negative-ion surface conversion technology to measure composition and energy spectra of neutral atoms (H, D, <sup>3</sup>He, <sup>4</sup>He, and O) at 10-500 eV. LENA consists of a collimator, conversion unit, extraction lens and acceleration region, dispersive electrostatic energy analyzer, and time-of-flight (TOF) mass analyzer with position-sensitive particle detection. Particles enter the instrument through a collimator with elevation acceptance defined by the height of the collimator. Neutrals are converted to negative ions through near specular reflection from a low-work- function cesiated tungsten conversion surface [Wurz et al., 1995]. The surface is segmented to cover a 90° azimuthal acceptance.

Beyond the conversion surface, LENA is an ion mass spectrograph. Neutrals converted to negative ions at the Cs surface are accelerated away from the conversion surface and measured by a spherical electrostatic analyzer. The electrostatic analyzer is dispersive in energy and focusing in elevation angle.

The three main sources of instrument background for LENA are UV photons, photoelectrons from the conversion surface, and negative ions produced by attachment of photoelectrons to residual gas molecules. UV photons scattered at near specular angles from the conversion surface enter a light trap at the back, while the electrostatic analyzer provides further multiple bounce rejection. Photoelectrons from the conversion surface are separated from the negative ions and diverted into a trap by a weak magnetic field between a small magnet at the back of the conversion surface and another at the dispenser. This magnetic field also traps electrons scattered through the collimator. Ion background from residual gas is minimized by accelerating photoelectrons away from the sensitive region. Any negative ions that are thereby produced will be discriminated against by their lower energies relative to those produced on the surface.

LENA has one operation mode and one surface regeneration mode. In a typical orbit, the shutter will open after a perigee pass, and low-energy neutral atom imaging will proceed throughout the orbit until near perigee, when the shutter will close again. Approximately every 10 days the instrument will be cycled autonomously through the conversion surface regeneration mode.

### 3.1.2 - Medium Energy Neutral Atom [MENA] Imager

The MENA imager is a slit camera with straight-through optics, which samples and resolves simultaneously all velocities, all polar angles within a 107° fan, and all masses. This spectrographic feature is very important for magnetospheric imaging because the weak fluxes of neutral atoms require the instrument to have a high duty cycle.

The MENA analyzer consists of a collimator, UV rejection grating, start foil, position-sensitive anode, TOF analyzer, and pulse-height analyzer. The collimator plates use electrostatic deflection to reduce charged particle background. The other significant background that must be eliminated is ultraviolet light from the Sun and geocorona. The UV grating acts as a wave guide to reduce the Lyman Alpha UV fluxes by a fraction of  $10^{-4}$ . The grating also reduces the neutral atom flux by 90%. Velocity analysis (through TOF measurements made with the start/stop MCP), combined with pulse-height analysis, yields mass resolution sufficient to separate H and O.

### 3.1.3 - High Energy Neutral Atom (HENA) Imager

HENA is a slit camera with a 90° x 120° field of view and a segmented focal plane incorporating an imaging solid-state detector (SSD) array in one portion and an MCP with position-sensitive anode in the other. Pulse height analysis of the SSD pulses provides total energy, which, combined with the TOF velocity determination, yields neutral atom mass. The MCP pulses are also pulse-height analyzed, yielding sufficient separation of H and O. Each pixel is viewed both by the SSD array and the MCP as the scene is scanned. HENA acquires angular images by locating the start pulses on the entrance slit and the stop pulses in the image plane. The collimator serves to suppress charged particle entry by biasing adjacent collimating plates at  $\diamond$  10 kV.

The UV background is suppressed by a combination of (1) a C-Si foil that reduces the UV flux, (2) the insensitivity of the SSD to UV photons, and (3) a triple-coincidence system for the MCPs in which start and stop pulses must fall within valid time windows, and a second stop from the back of a foil placed directly over the stop MCP is collected by the coincidence stop MCP.

All HENA potentials are static except for infrequent adjustments of MCP gain. After activation and checkout, HENA runs in a single operational mode. Some choices of data product priorities can be made as software options, providing, for example, a periodic (e.g., monthly) calibration mode to check the TOF/PH identification of atomic species, the pulse-amplifier chains, and the binning logic.

## 3.2 - Photon Imagers

There are three photon imagers required by IMAGE. The EUV instrument images resonantly scattered solar emissions from plasmaspheric He<sup>+</sup> at 30.4 nm. Two FUV instruments, SI (Spectrographic Imager) and WIC (Wideband Imaging Camera) image the Earth's electron and proton auroral emissions. A Geocorona Oxygen Cell (GEO), which is part of SI, images the hydrogen geocorona. General characteristics of the imagers are listed in Table 3.3 below.

Inst.	Measurement Type	Focal Length (mm)	Aperture (mm <sup>2</sup> )	Wave-length (nm)	Wave-length Res. (nm)	Instant. FOV (deg)	Tot. FOV (deg)	Pixel FOV (deg)	Sensitivity (c/R/pixel)	Time Res. (min)	Spatial Res. @7R <sub>E</sub> (km/pix)
EUV	Plasmaspheric He <sup>+</sup> 30.4 nm	75	25 (3)	30.4	5.0	30 x 90	90 x 360	0.5 x 0.5	2.4	2	640 x 640
FUV/SI	Auroral LBH (narrow band), Lyman-Alpha	68	112	121.8 & 135.6	0.2 & 3	15 x 15	15 x 360	0.11	0.05	2	90 x 90
FUV/GEO	Geocoronal Lyman-Alpha	60	132	121.6	0.2	1 x 1 (3 cells)	60 x 360	1	0.1	2	N/A
FUV/WIC	Auroral LBH (broad band)	22.4	60.8	140 $\diamond$ 190	N/A	30 x 22.5	22.5 x 360	0.09	0.1	2	70 x 70

Table 3.3 Photon Imager Instrument Performance Parameters

### 3.2.1 - He<sup>+</sup> 30.4 nm Imager (EUV)

Effective imaging of plasmaspheric He<sup>+</sup> requires global "snapshots" in which the high apogee of the IMAGE mission and the wide FOV of the EUV imager provide, in a single exposure, a map of the entire plasmasphere from the outside with a sensitivity of 0.2 count/s-pixel-Rayleigh (R), a spatial resolution of 0.1 R<sub>E</sub>, and a time resolution of several minutes. The 30.4-nm feature is easy to measure because it is the brightest ion emission from the plasmasphere, it is spectrally isolated, and the background is negligible. Measurements are easy to interpret because the plasmaspheric He<sup>+</sup> emission is optically thin, so its brightness is directly proportional to the He<sup>+</sup> column abundance.

EUV consists of three identical sensor heads serviced by a common electronics module. It employs elements of new technology, multilayer mirrors. Because it is simple and lacks moving parts, the EUV is rugged and reliable. Each sensor head has a field of view of 30° x 30°. The three sensors are tilted relative to one another to cover a fan-shaped instantaneous FOV of 90° x 30°. As the satellite spins, the fan sweeps a 90° x 360° swath across the sky.

Each EUV sensor achieves high throughput and a wide field of view by using a large entrance aperture and a single spherical mirror. A multilayer reflective coating on the mirror selects a narrow 5-nm passband around the 30.4 nm line. To circumvent the red leak in the multilayer mirror, the filter blocks H Lyman, a contamination from the geocorona. The detector consists of two curved, tandem MCPs with an alkali halide front surface photocathode. The detector's spherical input surface minimizes the effects of spherical aberration. Readout from the detector is from a 128 x 128 wedge and strip anode. The sensitivity (accounting for the duty cycle inherent in a spinning spacecraft) is 0.2 count/(sec pixel) per R, where the pixel size is taken to be 0.1 R<sub>E</sub>. By summing pixels to make a spatial resolution element (called a resel) of 0.5 R<sub>E</sub>, the count rate is 5 counts/(sec resel) per R.

### 3.2.2 - Far Ultraviolet Imagers (FUV)

Science requirements driving FUV imager designs are (1) to image the entire auroral oval from a spinning spacecraft at 7  $R_E$  apogee altitude, (2) to separate spectrally the hot proton precipitation from the statistical noise of the intense, cold geocorona, and (3) to separate spectrally the electron and proton auroras. FUV consists of two imagers that combine high spectral discrimination, high spatial resolution, and the greatest possible sensitivity to meet these requirements.

In the FUV range up to  $\sim 160$  nm, there are several bright auroral emission features that compete with the dayglow emissions. For the electron aurora, the brightest is 130.4 nm OI, which is multiply scattered in the atmosphere and thus cannot be used for auroral morphology studies. The next brightest is the 135.6 nm OI emission. Separation of the 130.4 and 135.6 nm lines necessitates the use of a spectrometer because even reflective narrow-band filter technology cannot satisfy the  $\sim 3$  nm wavelength resolution requirement. Above 135.6 nm, weak LBH lines can be detected using narrow-band filter technology. Separate imaging of the intense, cold geocorona (Lyman Alpha emissions at 121.6 nm) and the less intense, Doppler-shifted Lyman Alpha auroral emissions requires significantly higher spectral resolution (0.2 nm).

**Spectrographic Imager (SI).** The relatively high wavelength resolution requirement is satisfied by the SI. The 0.2-nm wavelength resolution drives the size of the instrument and consequently the number of mirrors in the optics system. Also the narrowness of the slits in the spectrometer limit the dwell time during which a pixel is in the field of view.

The SI is a Wadsworth spectrometer, which uses a diffraction grating to produce separate images of 135.6 nm emissions from the electron aurora and 121.8 - 122.2 nm doppler-shifted Lyman Alpha emissions from the proton aurora. The 130.4 nm oxygen airglow emission and the geocorona 121.6 Lyman Alpha emission are blocked out. The detectors use a KBr photocathode on a  $MgF_2$  window image tube with MCP intensification. The intensified image is detected by a crossed delay- line type detector with two 32 x 128 pixel active areas. Added to the SI is a Geocorona Oxygen Cell (GEO), which provides three  $1^\circ$  narrow-band photometer channels of geocorona data at 121.6 nm.

The SI has only one mode of operation. For some orientations of the spin axis, the Sun may enter the field of view of SI at some spin phases. As with EUV, the control microprocessor will automatically reduce the high voltage to the MCPs to avoid excessive counting rates. The filters will prevent damage to the detector by focused visible sunlight.

**Wideband imaging camera (WIC).** The relatively high sensitivity requirement for auroral imaging is satisfied by the WIC. This imaging camera uses the basic design flown on the Freja and Viking [Auger et. al, 1987] satellites to measure the auroral LBH emissions in a relatively broad band from 140 nm to 190 nm. The large field of view permits a long dwell (or integration) period and increases the apparent sensitivity.

The WIC optics design is identical to that of the Freja camera. Incident photons pass through a filter that blocks the Lyman Alpha emissions and protects the detector from direct, focused sunlight. The primary and secondary mirrors have a coating that is highly reflective ( $>60\%$ ) in the FUV but has minimum ( $<3\%$ ) reflectance out of band. MCPs are used to intensify the image, which is produced on a phosphor and fiber-optically coupled to a diode array.

Operation of the WIC is essentially identical to that of SI. Readout occurs once per  $0.1^\circ$  of rotation for a frame rate of 30 frames/s at 0.5 rpm. The camera data are digitized and co-added in memory and the addresses are selected according to the rotational phase of the spacecraft. This technique minimizes the distortion correction required by the imager.

### 3.3 - Radio Plasma Imager (RPI)

The Radio Plasma Imager (RPI) is a transmitter/receiver system that responds to the science requirement for the continuous remote sensing of plasma densities, structures and dynamics in the magnetosphere and plasmasphere. The instrument measures the time delay, angle-of-arrival, and Doppler shift of magnetospheric echoes over the frequency band from 3 kHz to 3 MHz. This frequency range makes possible remote sensing of plasma densities from 0.1 to  $10^5 \text{ cm}^{-3}$ . The performance parameters for the RPI to meet science objectives are listed in Table 3.4 and Table 3.5 below. Programmable operational modes selected within the limits listed in Tables 3.4 and 3.5 will focus on specific magnetospheric and plasmaspheric features.

Measurement	Nominal Resolution	Limits
Echo Range	500 km	0.1 to 5 $R_E$
Angle-of-Arrival	$1^\circ$ at 40 dB S/N	resolution = $2/[S/N]$
Doppler	0.125 Hz	75 Hz
Time	8 seconds/frequency	4 seconds/frequency

Table 3.4 RPI Measurement Performance Parameters

Parameter	Nominal	Limits
RF Power	10 W	10 W
Pulse Width	53 msec	3.2 to 125 ms
Receiver Bandwidth	300 Hz	fixed at 300 Hz
Pulse Rate	2 pps	1 to 5 pps
Frequency Range	10 to 100 kHz	3 kHz to 3 MHz
Frequency Steps	5%	$\geq 100$ Hz
Coherent Integ. Time	8 seconds	$> 2$ seconds

Table 3.5 RPI Instrument Performance Parameters

RPI will have two crossed 500-m tip-to-tip thin wire dipole antennas in the spin plane, and a 20-m tip-to-tip tubular dipole antenna along the spin axis. All three antennas will be used for reception to determine the angles of arrival of the echoes [Calvert et al., 1995].

The large distances, low power, and short antennas (relative to the wavelength) require onboard signal processing. Pulse compression and coherent spectral integration techniques will be used to achieve the required signal-to-noise (S/N) ratios. For a large part of the frequency range, S/N is larger than 100, assuring 1 $\sigma$  angular resolution. The range resolution of 500 km is defined by the 3.2-ms width of the transmitted sub-pulses. The number of sounding frequencies selected for a given measurement, together with the coherent integration time, determines the time resolution, since measurements are taken continuously.

## 4.0 - IMAGE End-to-End Data Flow

The IMAGE mission will maintain a series of World Wide Web (WWW) pages which provide the latest information about all aspects of IMAGE, including the type and accessibility of IMAGE data. These pages are located at the following URL: <http://image.gsfc.nasa.gov/>

### 4.1 - Overview

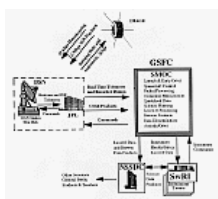
Data will be nominally downlinked once per orbit using the DSN 34 meter subnet and forwarded to the Science and Mission Operations Center (SMOC) located at GSFC. Because of the volume of the data, and latency within the DSN system, this transfer could take as long as nine hours but as short as one hour. Once the data from an orbit have been delivered to the SMOC, Level-0 and Level-1 science data processing will be initiated. The resulting products will be made immediately available to anyone on an IMAGE web site maintained in the SMOC. These products will also be forwarded to the NSSDC for permanent archiving and public distribution. See Figure 4.1 for a graphical description of the IMAGE data system.

### 4.2 - Science and Missions Operations Center

The IMAGE observatory will be operated from the SMOC which is located at GSFC. The Spacecraft Control Team will operate the SMOC and will perform all mission operations including execution of the consolidated science data plan provided weekly by the PI, spacecraft commanding and command management, health and safety monitoring and control, Level-0 and Level-1 science data processing, and data distribution. The consolidation of all of these functions, which have been traditionally been performed in separate facilities at GSFC, into a single facility will minimize the size of the ground operations staff and the cost of operations. Data services at the SMOC will include a WWW interface for accessing the previous week's worth of IMAGE data and information including Level-0 files for download, Level-1 files for download and/or display, and data accounting and processing status information.

### 4.3 - Data Products and Access Overview

This section will discuss all the IMAGE data products, how and where they are generated, and how and when they will be accessible.



**Fig. 4.1** The IMAGE Data System

#### 4.3.1 - Level-0 Data

Each Level-0 data file will consist of a time-ordered set of source data packets from each instrument and a standard file header consistent with the ISTP Level-0 Guidelines (560-1DFD/0190). Two Level-0 data files will be generated for each instrument per orbit, a file of instrument science data packets, and a file of instrument housekeeping packets. The SMOC will post the most recent Level-0 data on the IMAGE web pages, in addition to providing it on a daily basis to the NSSDC. A quicklook version of each of these files will be generated immediately upon receipt of data from DSN, and a final version will be generated 3 days later, after recovering lost data.

#### 4.3.2 - Level-1 Data

In order to accomplish the IMAGE scientific goals, the ability to quickly survey a vast array of scientific data being generated by each instrument is essential. The result of Level-1 data processing in the SMOC will typically be an image referred to as a Browse Product (BP). All BP data sets are created as Common Data Format (CDF) files using the ISTP Guidelines (see Kessel et al., 1994) for Key Parameter Data. The SMOC will post the most recent BP data on the IMAGE web pages in addition to providing it on a daily basis to the NSSDC. A quicklook version of each of these files will be generated immediately upon DSN pass completion. A delay of 3 days will occur if lost data needs to be recovered from DSN. The Browse Product summaries for each IMAGE instrument are given in Table 4.1.

The software algorithms for the BP production will be provided by each of the instrument teams and will be integrated into the SMOC data production pipeline prior to the launch. The software and associated documentation for the BPs will be archived at the NSSDC.

#### 4.3.3 - Level-2 and Higher Level Data Products

Higher level IMAGE data products are being designed to illustrate magnetospheric structures and dynamics. All binary higher level data products will also be in the ISTP/Common Data Format. Each of the instrument teams (IT) have facilities at their institution that are used in processing, analyzing, and correlating IMAGE data. It is expected that some IMAGE investigators will routinely generate additional instrument data products. These products, along with associated documentation and the generation software, will be delivered to the NSSDC for long-term archiving and community-wide distribution. Table 4.2 provides an overview of the higher Level data products that have currently been identified to be archived.

#### 4.3.4 - Attitude and Orbit Products

A daily attitude history file shall be produced in the SMOC. This file will be generated as an ISTEP-standard CDF file, and will contain the attitude quaternions as determined by the spacecraft on-board computer. Orbit determination will be performed by the JPL/DSN and will be retrieved via FTP by the SMOC, where it will be converted into an orbit ISTEP-standard CDF file containing spacecraft position and velocity vectors. This data will also be delivered to the NSSDC for long-term archiving and distribution.

#### 4.4 - Data Archiving and Distribution

The Level-0, Level-1, attitude and orbit data products will be sent via FTP to the NSSDC daily for permanent archive and public distribution. These data products will only be held temporarily in the SMOC until they can be copied onto CD-ROM or DVD and sent to selected IMAGE investigators and participating scientists. The CD-ROMs/DVDs produced in the SMOC will conform to the ISO 9660 standard, which defines both the physical and logical format of the CD-ROM/DVD. This approach ensures that most CD-ROM/DVD drives on most platforms will be able to read these disks. In addition, the CD-ROM/DVD produced by the SMOC will follow other emerging NASA standards, guidelines, and practices, especially the use of Standard Formatted Data Unit (SFDU), and a file naming and directory structure which will be compatible with most platforms.

#### 4.5 - Archival Data Volume

The estimated volume of mission data acquired over nominal 2-year lifetime (based on average bits per orbit, a 13.5 hour orbit, and Level-1 & 2 data products, which are estimated at 20% of the Level-0 volume) are shown in Table 4.3. The attitude and orbit data volume will be approximately 2 GB total. Based on these estimates the total IMAGE Observatory data volume to be archived at the NSSDC will be approximately 280 GB over the 2-year lifetime of the mission.

#### 4.6 - Archive Data Access

The NSSDC's on-line archive facility that will be used for rapid access to all the archived IMAGE data is called the NASA/NSSDC Data Archive and Distribution Service, or NDADS. The purpose of the NDADS system is to manage public archival data. Since the SMOC's primary purpose is to process and distribute the most recent IMAGE data, the SMOC is not designed to manage all the retrospective requests for older processed and archived IMAGE data. Investigators using IMAGE data who desire retrospective IMAGE data will be able to access the NSSDC's NDADS archive. NDADS provides archival data services not only to IMAGE scientists, but also to the worldwide science user community and the public.

One of the most important features of the NDADS system is that it provides the capability for scientists to retrieve data from the archive by several methods. The public data archive can easily be accessed through the NSSDC's automated retrieval mail system, or ARMS or the WWW. The NDADS system is operational 24 hours/day, 7 days/week and is a major archive and data distribution facility on the Space Physics Data System.

Investigation	Browse Product	Time Resolution
HENA	1. NAI image within the 10 -200 keV or 2. During active times one NAI image	4 min. 2 min.
MENA	1. NAI image within the 1 -30 keV or 2. During active times one NAI image	4 min. 2 min.
LENA	1. NAI image from 10 - 300 eV or 2. During active times one NAI image	4 min. 2 min.
RPI	1. Plasmagram - Electric field amplitude in $V^2/m^2/Hz$ given as a function of time delay vs frequency (frequency ranges from 3 kHz to 3 MHz depending on instrument mode and may be as many as 128 values) 2. Magnetopause and Cusp Skymap (20-60 kHz) 3. Plasmapause Skymap (120-250 kHz)  Notes: Skymaps are radio images illustrating echo location and doppler	2 min. 2 min. 2 min.
FUV/WIC	1. Wide band auroral image (140-190 nm) in GCI coordinates  Notes: Time assigned to an image is the center time of the integration period.	2 min.
FUV/SI	1. Auroral zone images at 121.7-122nm and 135.6nm in GCI coordinates	2 min.
FUV/GEO	1. Geocorona images at 121.6 +/-0.5nm in GCI coordinates	2 min.
EUV	1. 30.4 nm images of resonance He <sup>+</sup> emission in GCI coordinates	2 min.

Table 4.1 Level 1 Data Products (Browse Products)

Investigation	Higher Level Data Products	Time Resolution
HENA	1. Ring current equatorial ion flux as a function of R, MLT, & pitch angle	2 min.
MENA	1. Ring current equatorial ion flux as a function of R, MLT, & pitch angle	2 min.
LENA	1. Integrated H <sup>+</sup> & O <sup>+</sup> ion outflow out of polar cap 2. At perigee +/- 2 hours, H <sup>+</sup> & O <sup>+</sup> ion outflow versus latitude, MLT, & energy	2 min.
RPI	1. Magnetopause $f_p$ , density, and location as a function of time 2. Plasmapause location as a function of time 3. Cross-section contour image maps of the plasmasphere in the IMAGE orbit plane	2 min. 2 min. Every Orbit
FUV/WIC	1. Electron energy deposition in auroral zone versus time, latitude, and MLT	2 min.
FUV/SI	1. Electron and proton morphology in auroral zone versus time, latitude, and MLT	2 min.
FUV/WIC & SI	1. Mean energy in precipitating electrons as a function of time, latitude, and MLT	2 min.



<b>FUV/GEO</b>	1. geocoronal densities versus location 2. limited proton auroral morphology for comparison to FUV/SI	2 min.
<b>EUV</b>	1. Density and distribution of He <sup>+</sup> ions in the magnetosphere, primarily in the plasmasphere and near plasmasphere regions, however, for long integration times may be able to follow cold plasma flows out to the magnetopause.	2 min.

**Table 4.2** Higher Level Data Products

Instrument	Level-0 (GB)	Level-1 (GB)	Level-2 (GB)
<b>LENA</b>	4.0	0.8	0.8
<b>MENA</b>	23.7	4.7	4.7
<b>HENA</b>	21.9	4.4	4.4
<b>RPI</b>	67.5	13.5	13.5
<b>EUV</b>	19.1	3.8	3.8
<b>FUV</b>	51.7	10.4	10.4
<b>CIDP</b>	2.1	0.4	0.4
<b>Spacecraft</b>	7.8	1.6	1.6
<b>Total</b>	<b>197.8 GB</b>	<b>40.0 GB</b>	<b>40.0 GB</b>

**Table 4.3** Estimated Volume of Mission Data and Data Products

## 5.0 - Data Rights and Rules for Data Use

The IMAGE data are open to all scientists and the public. There are no proprietary periods associated with any of the IMAGE data products. All IMAGE data (including Level-0) will be archived at the NSSDC.

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## Appendix A - Acronym List

ADAC	- Attitude determination and control system
CDF	- Common Data Format
CoI	- Co-Investigator
COTS	- Commercial Off-The-Shelf
DPS	- Digisonde Portable Sounder
DSN	- Deep Space Network
DVD	- Digital Versatile Disk
EUV	- Extreme Ultraviolet Imager
ESA	- European Space Agency
f <sub>p</sub>	- Plasma Frequency
FDL	- Flight Dynamics Facility
FOV	- Field of View
FTP	- File Transfer Protocol
FUV	- Far-Ultraviolet Imager
GB	- Gigabytes
GCI	- Geocentric Celestial Inertial Coordinate System
GSE	- Geocentric Solar Ecliptic Coordinate System
GSM	- Geocentric Solar Magnetospheric Coordinate System
GSFC	- Goddard Space Flight Center
HENA	- High-Energy Neutral Atom Imager
IMAGE	- Imager for Magnetopause-to-Aurora Global Exploration
IT	- Instrument Teams
LBH	- Lyman-Birge-Hopfield (bands of FUV emissions from N <sub>2</sub> )
LENA	- Low-Energy Neutral Atom Imager
MENA	- Medium-Energy Neutral Atom Imager

MCP - Multi-Channel Plate  
MIDEX - Medium Explorer  
MO&DA - Mission Operations and Data Analysis  
NAI - Neutral Atom Imager  
NASA - National Aeronautics and Space Administration  
NASCOM - NASA Communication Network  
NSI - NASA Science Internet  
NSSDC - National Space Science Data Center  
OI - Neutral atomic oxygen  
OSP - Orbiting Satellites Project  
PI - Principal Investigator  
PDMP - Project Data Management Plan  
QL - Quicklook - Telemetry that is used to monitor health and safety of S/C and instruments.  
R<sub>E</sub> - Earth Radii  
RPI - Radio Plasma Imager  
S/N - Signal-to-Noise  
SEC - Space Environment Center  
SFDU - Standard Formatted Data Units  
SMOC - Science and Mission Operations Center  
SSR - Solid State Recorder  
SwRI - Southwest Research Institute  
TOF - Time of Flight  
URL - Uniform Resource Locator  
WIC - Far Ultraviolet Wideband Imaging Camera  
WWW - World Wide Web

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